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THE INFLUENCE OF DIVERSIFIED NITROGEN AND LIMING FERTILIZATION ON THE YIELD AND BIOLOGICAL VALUE OF LETTUCE

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Abstract. Nitrogen and calcium are the two elements, among other main nutrients, responsible for proper nutrition of plants. The experiments conducted with lettuce of the Omega F_1 variety aimed at an analysis of differentiated methods of nitrogen and calcium carbonate fertilization on the general crop yield and its biological value. After the plants were collected, the fresh weight of the plants, the dry mass, the vitamin C content, extract and protein contents were measured. After the vegetation period of plants samples of medium were collected and, with use of 0.03 M extract of acetic acid, the contents of mineral nitrogen, phosphorus, calcium and magnesium were determined, as well as the pH and EC values of the medium measured. The crop yield of fresh leaves mass was significantly dependent on the used dose of nitrogen and calcium carbonate. The largest lettuce crop yield was recorded in objects fertilized with 0.4 g · dm^{-3} of nitrogen and the higher dose of calcium carbonate (283 g·$plant^{-1}$). The vitamin C, extract and protein contents were dependent on the dose of nitrogen. The largest quantity of vitamin C characterized the lettuce plants fertilized with the largest dose of nitrogen and the higher dose of calcium carbonate (33.7 mg·100 g^{-1} fr. m.). The application of calcium carbonate in 14 g · dm^{-3} causes the calcium content of the medium to rise. The EC value of the medium was largely arisen under the influence of the mineral nitrogen and varied between 1.33 and 1.96 mS·cm^{-1}.

Key words: *Lactuca sativa*, mineral fertilization, vitamin C, protein

INTRODUCTION

Lettuce (*Lactuca sativa* L.) is the main leaved vegetable, cultivated both in open fields and under covers. The lettuce is consumed as fresh vegetable in comparably large quantities. Its leaves contain 95% of water, and their energy value is low. The vegetable contains vitamins C, B_1, B_2, E, carotene, potassium, calcium and iron as well as other

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nutrients, in much smaller amounts. The lettuce leaves also contain specific compounds – lactucerins that stimulate the functioning of thyroid, as well as mustard glycosides, fibre, folic acid and beta-carotene. Lettuce leaves are also a source of phenolic acids, that do possess antioxidant properties, and are described as inhibitors of cancerous diseases [Nicolle et al. 2004, Stępkowska 2004, Patil et al. 2005].

Within intensive horticulture the proper nutrition of the plants forms the main factor shaping the volume and quality of vegetable crops [Kader 2008, Fallovo et al. 2009]. Nitrogen and calcium are the two elements among the main (N, P, K, Ca, Mg) nutrients, that are responsible for proper nutrition state of the plants. Proper nitrogen fertilization causes the plants to maintain an intensively green colour of leaves. It is a key feature in cultivation of lettuce, as the colour is an indicator of the plants freshness [Michałek and Rukasz 1998]. Properly nourished plants contain up to 1–2% of $N\text{-}NO_3$ in their dry mass, while the insufficient amount of this element can be ascertained, when its content drops below 0.4% of the dry mass. The plants cultivated with deficiency of nitrogen are characterized by their slow growth, yellow-green leaves, lignification of tissues and, of course, low crop yields. Large deficiency of nitrogen can cause the growth of young leaves to halt, as well as prevent the heads from forming [Wasilewska 1999].

Calcium is an element occurring in plants in form of organic compounds (pectinates, oxalates, phytin); it is also present in cell walls, it activates enzymes, and can also occur in form of free ions. The role of calcium within a plant is connected to the division of cells, their elongation growth, functioning of mitochondria and chloroplasts. It also influences on the physical and physiochemical properties of the soil, its pH value, structure – and through structure also the water and air ratios. After liming the acquisition rate for plant nutrients changes significantly. The lettuce attainability of calcium is larger due to the presence of the physiological disease of “tipburn” [Hartz et al. 2007].

The aim of the conducted research was to ascertain the influence of differentiated nitrogen and calcium fertilization methods on the crop yield and biological value of lettuce. Furthermore, our work also takes the chemical analysis of medium nutrient contents and its pH and EC values, into consideration.

MATERIAL AND METHODS

The experiment with lettuce (*Lactuca sativa* L.) of the Omega F_1 variety was conducted in a greenhouse in spring (February–April) 2009 and 2010. The lettuce heads of the Omega F_1 are large, round and compact, reaching a mass of up to 500–600 g. Omega is a variety recommended for spring cultures, for early collection, because it is an early crop characterized by, as mentioned above, large heads. It can also give satisfactory crop yields when cultivated within the fall cycle. This particular variety is also characterized by its immunity against *Bremia lactucae* [Wasilewska 1999].

The lettuce seeds were sown on February, 24^{th}, bedded out to pallets on March, 7^{th} and the plantation into the pots took place on March, 19^{th}. The plants were grown in pots of the capacity of 2 dm^3 in seven replications. A replication was a pot with one plant. The experiment was established in complete randomization system. The base was intermediate peat, limed with calcium carbonate – accordingly in doses of 7 and

14 g·dm^{-3} of the medium. Raising doses of nitrogen (0.2; 0.4; 0.6; 0.8 g·dm^{-3}) in form of ammonium nitrate (34% N) were used, phosphorus was provided in form of triple superphosphate (20.2% P), potassium in form of potassium sulphate (41.5% K) and magnesium in form of magnesium sulphate (15.6% Mg). The doses of phosphorus, potassium and magnesium were equal for all the plants and amounted respectively: 0.5 P, 0.8 K, 0.5 Mg mg·dm^{-3}. The microelements were delivered to the medium in one-off dose, before plantation, in the following doses: 8.0 Fe; 13.3 Cu; 5.1 Mn; 1.6 B; 3.7 Mo; 0.74 Zn (mg·dm^{-3}), applying chelate – Fe; sulfates – Cu, Mn, Zn, boric acid, ammonium molybdate. Similarly to the microelements, the phosphorus was also applied to the medium in one dose, while nitrogen, potassium and magnesium were divided into three parts – one third before planting (19.03) and the remaining quantity double during vegetative period (01.04, 13.04).

After the plants were collected, during both years of the experiments, the fresh mass of the plants was determined, as well as their dry mass, with the use of dryer method; the vitamin C content in fresh material, with the use of Tillmans method [PN-A-04019 1998]; the extract with the use of refractometry; and the protein content by multiplying the total N content of the plant by a constant factor of 6.25. At the end of plant vegetation (24 April) the medium was collected and its contents of ammonium and nitrate nitrogen were measured in a 0.03 M solution of acetic acid with the use of Starck modified Bremner distillation method. The phosphorus content was measured with use of colorimetry using vanadium-molybdenum reagent (Nicolet Evolution 300 Spectrophotometer), potassium, calcium and magnesium with use of AAS method (Perkin-Elmer Analyst 300). Furthermore the values of pH and EC were also set for water solution with a constant medium to water ratio of 1:2.

The results in regard to the crop, its biological value and the medium were subject to a statistical analysis of their variance, by setting the smallest significant difference (LSD), based upon the Tukey's test, at the significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

The dose of mineral fertilizers used in gardening production is important for various reasons, especially for the granting of high crop yields, through low production costs and to the lessening of the environmental footprint of the culture [Li et al. 2010]. The experiments of Nurzyński et al. [2009] do show the need to use N and Ca during the cultivation of the plants, and recommend the N and $CaCO_3$ doses of the following values 0.3 g·dm^{-3} and 10 g·dm^{-3}.

The crop yield of the lettuce was on a high level (tab. 1). The differentiation of the doses of nitrogen and calcium carbonate had a significant influence on lettuce crop yield, with its highest values recorded with use of second dose of nitrogen and the higher dose of $CaCO_3$. After the experiment, the content of mineral nitrogen in this objects in the peat was 157 mg·dm^{-3} (66 mg·dm^{-3} N-NH_4 + 91 mg·dm^{-3} N-NO_3). The experiments conducted by Li et al. [2010] with use of celery do also show the significant influence of the dose of calcium, as well as magnesium and phosphorus on both the fresh and dry mass of plants produced. Although our experiments with lettuce did not show significant differences in the content of dry mass, the concentration of this parameter did not differ much from the results obtained by Nurzyński et al. [2009]. Tzortzakis [2010], when analysing the influence of calcium on the content of dry mass in endive, reached significant differences in its content, which was in range from 4.9 to 6.3%. Adamczewska-Sowińska and Uklańska [2010], also examining endive, ascertained no significant influence of the dose of nitrogen on the concentration of dry mass.

One of the parameters setting the biological value of vegetables is their vitamin C content, which depends on numerous factors, for example on the crop collection date, variety of the plant used [Olfati et al. 2011] as well as the fertilization [Koudela and Petříková 2008]. The vitamin C content of the lettuce, subject to our examination, was at the level of 27.6 mg·100 g^{-1} of fresh mass. The increase of vitamin C content in lettuce was recorded along with the nitrogen rate elevation. Use of a double $CaCO_3$ dose resulted in an increase of vitamin C in the tested plants by 11% compared to single dose.

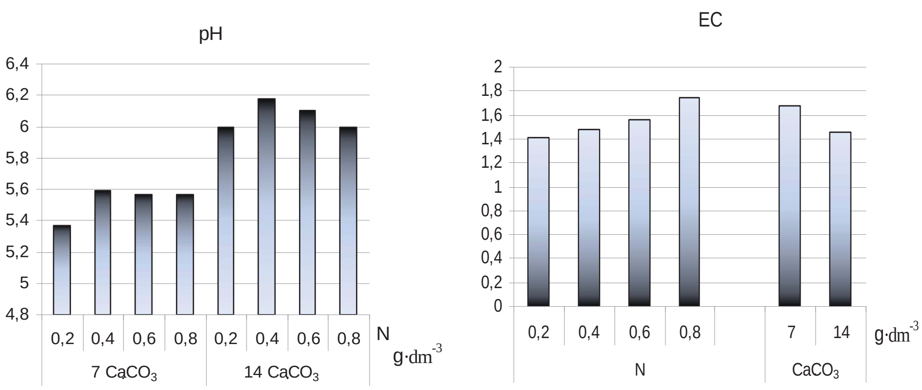
Table 1. The yield, dry mass, vitamin C, extract and protein content in lettuce (mean from 2009–2010)
Tabela 1. Plon, zawartość suchej masy, witaminy C, ekstraktu i białka w sałacie (średnio z 2009–2010)

Dose – Dawka g·dm^{-3} N	Dose – Dawka g·dm^{-3} $CaCO_3$	Yield g·$plant^{-1}$ Plon g·$roślina^{-1}$	Dry mass Sucha masa %	Vitamin C Witamina C mg·100g^{-1} fr. m.	Extract Ekstrakt %	Protein Białko % d. m.
0.2	7.0	238.45	5.23	24.72	2.94	25.33
0.4	7.0	256.91	4.60	29.77	2.38	31.30
0.6	7.0	234.91	5.04	26.96	2.24	32.71
0.8	7.0	200.64	5.18	22.47	2.90	35.06
$\bar{x}$		232.72	5.01	25.98	2.62	31.10
0.2	14.0	262.64	4.72	24.72	3.08	26.05
0.4	14.0	282.64	5.16	24.72	2.18	30.78
0.6	14.0	242.55	5.90	33.71	2.58	32.64
0.8	14.0	248.45	5.55	33.71	2.76	35.43
$\bar{x}$		259.07	5.33	29.21	2.65	31.22
0.2	$\bar{x}$	250.55	4.97	24.72	3.01	25.69
0.4	$\bar{x}$	269.77	4.88	27.24	2.28	31.04
0.6	$\bar{x}$	238.73	5.47	30.33	2.41	32.67
0.8	$\bar{x}$	224.55	5.36	28.09	2.83	35.24
$NIR_{\alpha = 0,05}$						
N Dose – Dawka		31.88	n.s. – r.n.	3.18	0.39	2.45
$CaCO_3$ Dose – Dawka		17.06	n.s. – r.n.	3.18	n.s. – r.n.	n.s. – r.n.
N Dose – Dawka × $CaCO_3$ Dose – Dawka		n.s. – r.n.	n.s. – r.n.	n.s. – r.n.	n.s. – r.n.	n.s. – r.n.

While analysing the influence of different varieties and the year of the culture on the vitamin C content, Koudela and Petříková [2008] achieved significant differences within the Frisby variety, and the average vitamin content was 290 mg·kg^{-1} of fresh mass. Significant differences in vitamin C content of chicory under the influence of different doses of nitrogen were observed by Biesiada and Kołota [2010], and Nurzyńska-Wierdak [2009] within garden rocket. The experiments of both Kołota and Czerniak [2010] and Dzida [2004] did not confirm the significant influence of nitrogen dose on the vitamin C content of chard. Venter [1983] reported that high doses of mineral fertilizer, especially nitric, do cause a significant lowering of the vitamin C content of vegetables.

The quality of the vegetable crop is also determined by the extract and protein contents of the plant. The contents of these parameters in the leaves of examined lettuce did vary. The differentiation of the dose of calcium carbonate did not influence on the contents of extract (2.62 and 2.65%) and protein (31.1 and 31.2) in lettuce. There were significant differences in case of nitrogen fertilization. The highest concentration of extract (3.01%) was achieved after use of the lowest dose of nitrogen, and the highest concentration of protein (35.24%) of dry mass after the highest rate applied. Nurzyńska-Wierdak [2009] proved that there was no significant influence of the dose of nitrogen on the protein content of rocket, with the average value of 35.75% of dry mass.

The influence of different nitrogen and calcium carbonate doses on the concentration of the basic mineral nutrients in the medium from beneath the cultivation of lettuce was shown in Table 2, and the pH and EC values on the Figure 1.



LSD – $NIR_{\alpha = 0.05}$ for N Dose – Dawka 0.303, $CaCO_3$ Dose – Dawka 0.16,
N Dose – Dawka × $CaCO_3$ Dose – Dawka n.s. – r.n.

Fig. 1. The influence of the N and $CaCO_3$ doses on the pH (H_2O) and EC (mS·cm^{-1}) values of the medium after the lettuce culture

Rys. 1. Wpływ dawki N i $CaCO_3$ na wartość pH (H_2O) i EC (mS·cm^{-1}) w podłożu spod uprawy sałaty

Among the many factors influencing the growth and the crop yield of the cultivated plants, the acidity of the soil is counted to one of the most important ones. The optimal pH range for most of grown gardening plants is between 5.5 and 6.5 [Nurzyński 2008]. During the presented experiment, the acidity of the medium after the lettuce crop has been collected, was well within the optimum range and depended slightly on the dose of nitrogen; similar connections were found in case of rocket cultures, after the vegetation period of the plants [Nurzyńska-Wierdak 2009], while the dose of calcium carbonate did largely influence on the pH value.

The conducted experiments have shown a dependence between diversified nitric-calcium fertilizing and the chemical composition of the medium. After the application of the smaller dose of calcium carbonate, the medium after the harvest of lettuce contained more mineral nitrogen, phosphorus and potassium, while when the larger dose of calcium carbonate was used – more calcium. Li et al. [2010] using different methods of calcium fertilization found similar dependencies within medium from the cultivation of the celery. This could have been caused by the differences in force, due to which monovalent and bivalent ions were acquired from the medium.

Table 2. Concentration of N, P, K, Ca, Mg in substrate at the end of experiment (means from 2009–2010)

Tabela 2. Zawartość N, P, K, Ca, Mg w podłożu po zakończeniu doświadczeń (średnio z 2009––2010)

Dose – Dawka $g \cdot dm^{-3}$		mg·dm^{-3} substrate – podłoża					
N	$CaCO_3$	N-NH_4	N-NO_3	P	K	Ca	Mg
0.2	7.0	35	20	263	363	1752	467
0.4	7.0	104	48	230	304	1804	425
0.6	7.0	198	111	211	383	1245	405
0.8	7.0	284	140	213	324	1474	363
$\bar{x}$		155	79	229	344	1568	415
0.2	14.0	49	35	178	313	4000	398
0.4	14.0	66	91	174	282	4054	431
0.6	14.0	113	124	158	378	3862	446
0.8	14.0	205	136	138	284	2477	342
$\bar{x}$		108	96	162	314	3598	404
0.2	$\bar{x}$	42	28	220	338	2875	433
0.4		85	69	202	293	2929	428
0.6		155	117	185	381	2553	426
0.8		245	138	175	304	1975	353
LSD – NIR$_{\alpha = 0,05}$							
N Dose – Dawka		27.02	32.37	39.55	n.s. – r.n.	980.44	78.72
$CaCO_3$ Dose – Dawka		14.31	n.s. – r.n.	20.94	n.s. – r.n.	519.07	n.s. – r.n.
N Dose – Dawka × $CaCO_3$ Dose – Dawka		45.86	n.s. – r.n.	n.s. – r.n.	n.s. – r.n.	n.s. – r.n.	n.s. – r.n.

The general concentration of salt in the medium (EC) plays a key role in proper uptake of water and nutrients dissolved. The EC value mostly depends on the content of all cations and anions in the medium, but in the largest degree on nitrate, potassium, sodium and magnesium ions [Nurzyński 2008]. This experiment has shown the largest EC value in case of the medium with the largest dose of nitrogen and the smaller dose of calcium carbonate. The use of larger dose of calcium carbonate resulted in lower EC values of the medium. Using three levels of Ca and Mg fertilization, Li et al. [2010] achieved the largest EC values in the medium fertilized with the largest amounts of Ca and Mg. The test medium has been gradually increased in the EC after the application of increasing doses of nitrogen.

CONCLUSIONS

1. The fresh yield of lettuce was significantly dependent on the dose of nitrogen and calcium carbonate applied.

2. The vitamin C, extract and protein contents did depend on the dose of nitrogen. The largest concentration of vitamin C was found for lettuce plants fertilized with 0.6 and 0.8 g · dm^{-3} dose of nitrogen in connection with the larger dose of calcium carbonate.

3. A significant influence of nitrogen and $CaCO_3$ concentration of $N\text{-}NH_4$, P and Ca in the substrate was recorded.

4. Reduced lettuce crops resulted from the increased concentration of salts (EC) in the medium.

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WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA AZOTOWEGO ORAZ WAPNOWANIA NA PLON I WARTOŚĆ BIOLOGICZNĄ SAŁATY

Streszczenie. Azot i wapń to dwa pierwiastki spośród głównych składników pokarmowych, które odpowiadają za prawidłowy stan odżywienia roślin. Przeprowadzone badania z sałatą odmiany Omega F_1 miały na celu przeanalizowanie wpływu zróżnicowanego nawożenia azotem i węglanem wapnia na plon i jego wartość biologiczną. Po zbiorze roślin, w każdym roku przeprowadzonych doświadczeń określono masę części nadziemnych, suchą masę, zawartość witaminy C, ekstrakt oraz białko. Po zakończeniu wegetacji roślin pobrano podłoże, w którym w wyciągu 0,03 M kwasu octowego oznaczono zawartość azotu mineralnego, fosforu, potasu, wapnia i magnezu oraz oznaczono wartość pH i EC podłoża. Plon świeżej masy liści uzależniony był w istotny sposób od zastosowanej dawki azotu i węglanu wapnia. Największy plon sałaty otrzymano w obiektach z drugą dawką azotu (0,4 g · dm^{-3}) i wyższą dawką węglanu wapnia (14 g · dm^{-3}) (283 g·$roślina^{-1}$). Zawartość witaminy C, ekstraktu i białka zależała od dawki azotu. Największą ilością witaminy C charakteryzowały się rośliny sałaty nawożone dawką azotu w ilości 0,6 i 0,8 g·dm^{-3} w połączeniu z wyższą dawką węglanu wapnia (33,7 mg·100 g^{-1} św. m.). Największą koncentracją ekstraktu charakteryzowały się rośliny nawożone dawką azotu w ilości 0,2 g·dm^{-3}, natomiast zwartość białka w roślinie wzrastała wraz ze wzrostem dawki azotu w podłożu. Wartość EC w podłożu zwiększała się przede wszystkim pod wpływem koncentracji azotu mineralnego i przyjmowała wartości od 1,33 do 1,96 mS·cm^{-1}.

Słowa kluczowe: *Lactuca sativa*, nawożenie mineralne, witamina C, białko

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